Introduction

While standard and custom fuel models are lists of values, special case fuel models are based on equations that determine the values needed by the surface fire spread model.

Fuels and fire behavior in aspen were studied by Brown and Simmerman (1986) who developed five unique models for western aspen with fuel characteristics related to the overstory/understory composition. Curing, the moisture content changes in live vegetation as it grows, matures, then declines toward dormancy, drives changes in fuel loads and surface area to volume ratios. Mortality modeling comes from work by Brown and DeByle (1987). Unique inputs to the aspen mortality model differentiate it from mortality models used with standard and custom fuel models.

Objectives

1. Identify the difference between a "special case" fuel model and standard and custom fuel models.
2. List input values for the western Aspen fuel model.
3. Show output variables for the western Aspen fuel model.
4. Calculate aspen mortality.
5. Contrast aspen curing level to curing level for dynamic fuel models.

Where This Lesson Fits In

This is a lesson in the Modeling Unit. It is assumed that the trainee has completed the four lessons in the Introduction Unit and has basic BehavePlus operation skills.

The trainee should also have completed the **Surface Fire Spread and Intensity Lesson**, which provides an overview of surface fuel models, including special case fuel models.

Assumptions and Limitations

The assumptions and limitations of the fire spread model described in the **Surface Fire and Intensity Lesson** apply to special case fuel models such as the Western Aspen Fuel Model.

Studies by Brown and Simmerman (1986) identified unique fuel load and surface-area-to-volume characteristics related to curing. This is different from the fuel load transfer used to represent curing in dynamic fuel models. The mortality model for aspen uses different inputs than the mortality model used for standard and custom models, so is included within the special case Aspen Fuel Model.

Western Aspen Details

BehavePlus incorporates separate models to describe fuels and mortality in the Western Aspen fuel model that are unique to the models used for the standard and custom fuel models. The 10-h fuel load and fuel bed depth are related to unique overstory/understory composition, each representing substantially different fire potential. Fine (1-h) Fuel Load, Live Fuel Load (herbaceous and woody), and Surface-Area-to-Volume Ratios are related to curing level in aspen. These unique characteristics separate this special case model from standard and custom fuel models.

There are five Aspen Fuel Models, which are related to the overstory/understory composition. Specific Fuel Bed Depths and 10-h Fuel Loads are assigned each model.

Aspen Fuel Model	Fuel Bed Depth, ft	10-h Fuel Load, tons/ac
Aspen/shrub	0.65	0.975
Aspen/tall forb	0.30	0.475
Aspen/low forb	0.18	1.035
(Conifer overstory) Mixed/shrub	0.50	1.340
(Conifer overstory) Mixed/forb	0.18	1.035

The following values are constant for all five aspen fuel models:

- Heat Content for live and dead fuels = 8,000 Btu/lb
- Moisture of Extinction = 25%
- 10-h Surface-Area-to-Volume Ratio (SA/V) = 109 ft^2/ft^3
- Live Herbaceous SA/V = 2,899 ft^2/ft^3

In standard and custom models, dynamic load transfer is used to simulate curing. This transfer is a function of Live Herbaceous Fuel Moisture Content (Scott and Burgan, 2005), or the percent to be transferred can be input directly. Aspen Curing Level, on the other hand, is the percent of

herbaceous biomass that is dead. The curing level affects the fuel loads and surface-area-to-volume ratios in the Aspen Fuel Model.

The following fuel loads and surface-area-to-volume ratios are adjusted based on curing level:

- 1-hr Fuel Load – increases with curing (as leaves and fine twigs dry)
- Live Herbaceous Fuel Load – decreases with curing (fewer live leaves)
- Live Woody Fuel Load – decreases with curing (decreased percentage not dormant)
- 1-h SA/V – increases with curing (dried plant parts shrink)
- Live Woody SA/V – decreases with curing (only larger stems remain alive)

The mortality model for aspen requires different inputs than the MORTALITY model used within BehavePlus for standard and custom models. The calculated Flame Length and user inputs of D.B.H. and Fire Severity are used in predicting aspen mortality (Brown and Simmerman 1986, Brown and DeByle 1987).

Two fire severity levels are defined:

- Low fire severity – vegetation litter is charred but not completely consumed, patches of unburned vegetation and litter remain, and
- Moderate^{+} fire severity – litter and some duff is consumed.

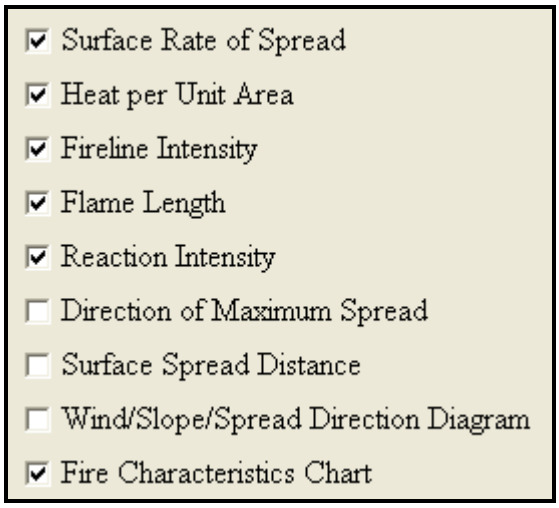
A Probability of Aspen Mortality is output from the model. This can be interpreted as the likelihood a specific tree will die or used as a multiplier to determine the number of trees in an area that will die.

Example Run

- Open the **BasicStart.bpw** Worksheet
- Enter "Western Aspen Lesson – Aspen/Shrub, Low Severity" in the **Description** window of the Worksheet.

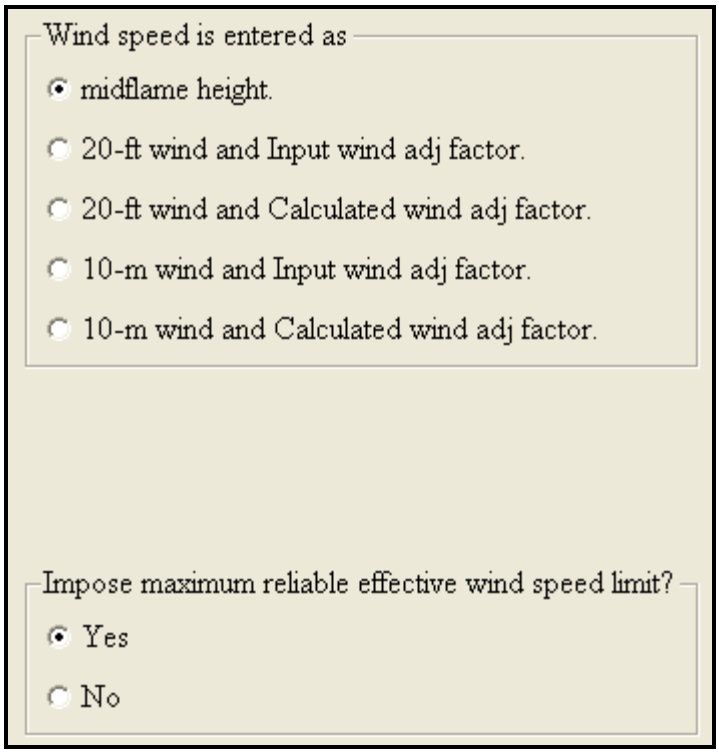
- Click **Module Selection > SURFACE > Options…**.

- On the **Basic Outputs** tab, select Surface Rate of Spread, Heat per Unit Area, Fireline Intensity, Flame Length, Reaction Intensity, and Fire Characteristics Chart.

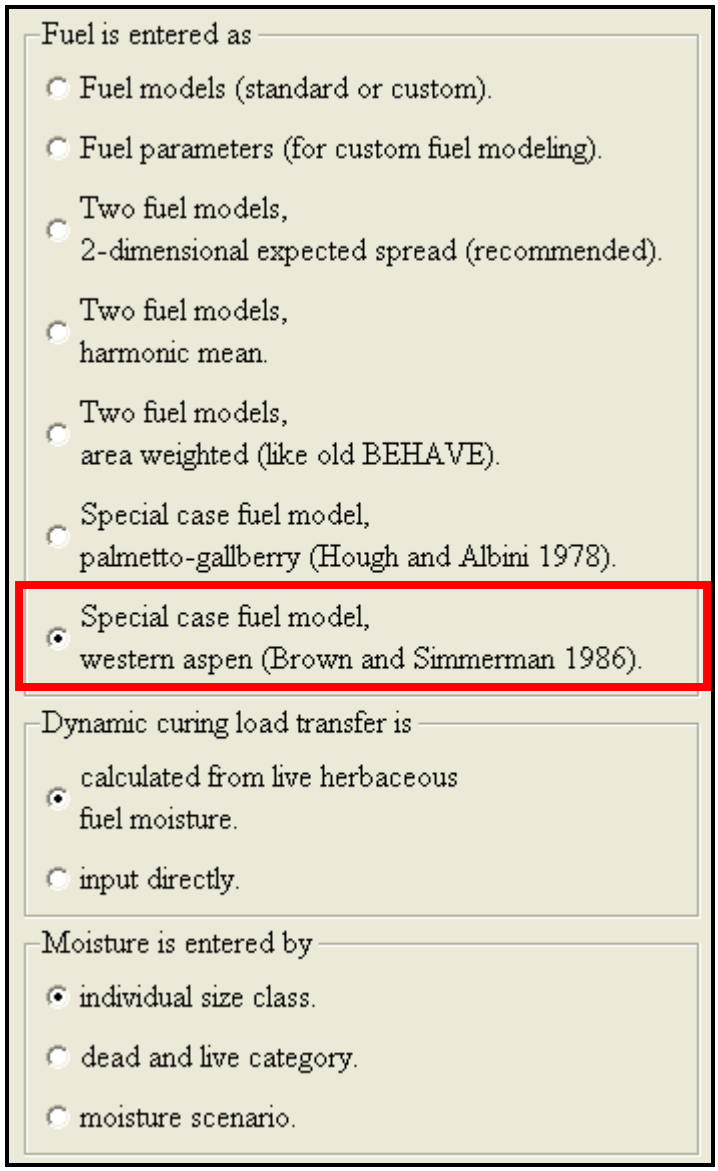


- Click the **Wind Speed** tab.
- Select **Wind speed entered as midflame height**.

The **Impose maximum reliable wind speed limit?** selection is ignored in this model. The limit is not imposed, regardless of whether **Yes** or **No** is selected.



- Click on the **Fuel & Moisture** tab.
- Select **Fuel is entered as Special case fuel model, western aspen (Brown and Simmerman 1986)**.

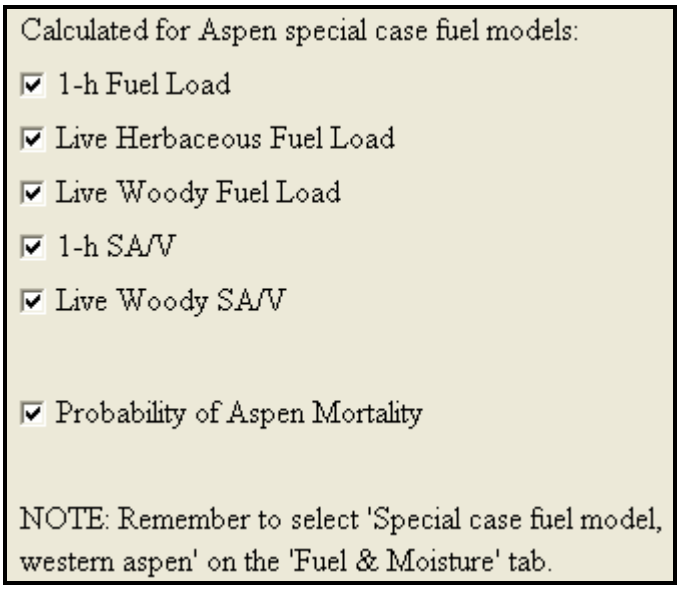


Dynamic curing load transfer is and the **Moisture is entered by** options are ignored for western aspen. This special case fuel model uses the level of curing to calculate load transfers.

- Select **Moisture is entered by individual size class**.

Calculations of fuel load, surface-area-to-volume ratio and mortality outputs for the western aspen model are initiated by checking the appropriate boxes through the **Aspen Outputs** screen.

- Click the **Aspen Outputs** tab.
- Select all outputs, including Probability of Aspen Mortality.

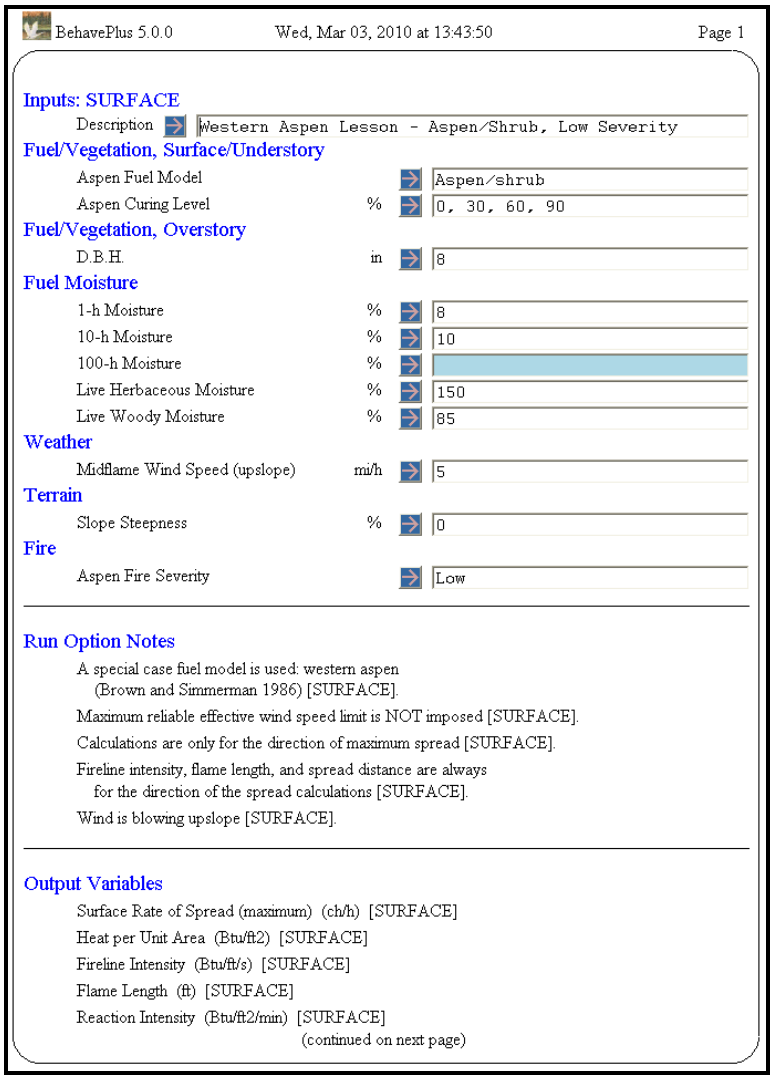


- Click **Ok** twice.

Enter values on the Worksheet as follows.

- Select the "Aspen/shrub" model, using the Guide button ( ).
- Select a range of Aspen Curing Level from "0" to "90" by "30"% steps.
- Enter "8" for D.B.H.
- Fuel moistures are "8" for 1-h, "10" for 10-h.
- Typically, live fuel moisture would decrease with increased curing. To simplify the entry, use "150"% for live herbaceous and "85"% for live woody moisture.
- Midflame wind speed is "5".
- Slope is "0".
- Aspen fire severity is "Low".

Your Worksheet should look like the one below.



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Inputs: SURFACE

Description: Western Aspen Lesson - Aspen/Shrub, Low Severity

Fuel/Vegetation, Surface/Understory

Aspen Fuel Model		Aspen/shrub
Aspen Curing Level	%	0, 30, 60, 90

Fuel/Vegetation, Overstory

D.B.H.	in	8

Fuel Moisture

1-h Moisture	%	8
10-h Moisture	%	10
100-h Moisture	%	
Live Herbaceous Moisture	%	150
Live Woody Moisture	%	85

Weather

Midflame Wind Speed (upslope)	mi/h	5

Terrain

Slope Steepness	%	0

Fire

Aspen Fire Severity		Low

Run Option Notes

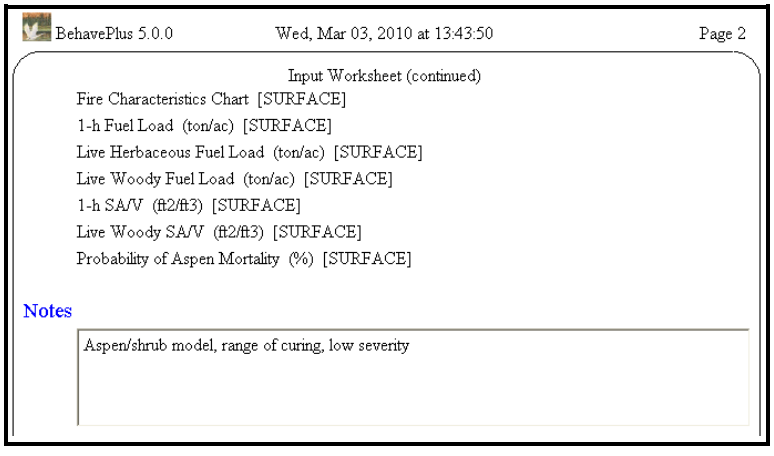
A special case fuel model is used: western aspen (Brown and Simmerman 1986) [SURFACE].
Maximum reliable effective wind speed limit is NOT imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind is blowing upslope [SURFACE].

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]
Heat per Unit Area (Btu/ft2) [SURFACE]
Fireline Intensity (Btu/ft/s) [SURFACE]
Flame Length (ft) [SURFACE]
Reaction Intensity (Btu/ft2/min) [SURFACE]

(continued on next page)

- Enter a description of this Run in the Notes box as shown below.



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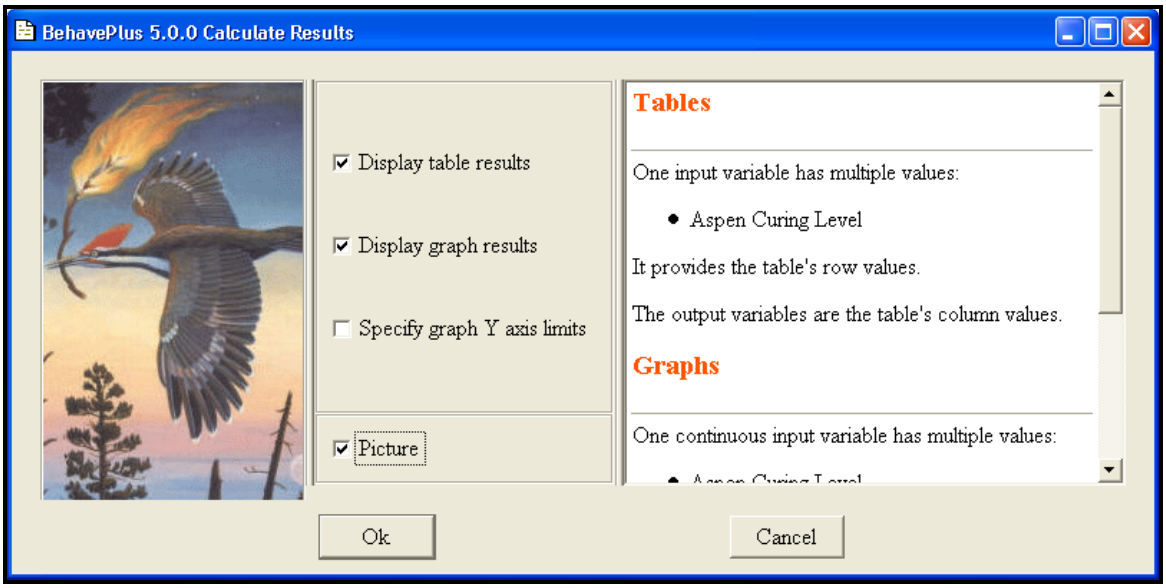
Input Worksheet (continued)

Fire Characteristics Chart [SURFACE]
1-h Fuel Load (ton/ac) [SURFACE]
Live Herbaceous Fuel Load (ton/ac) [SURFACE]
Live Woody Fuel Load (ton/ac) [SURFACE]
1-h SA/V (ft2/ft3) [SURFACE]
Live Woody SA/V (ft2/ft3) [SURFACE]
Probability of Aspen Mortality (%) [SURFACE]

Notes

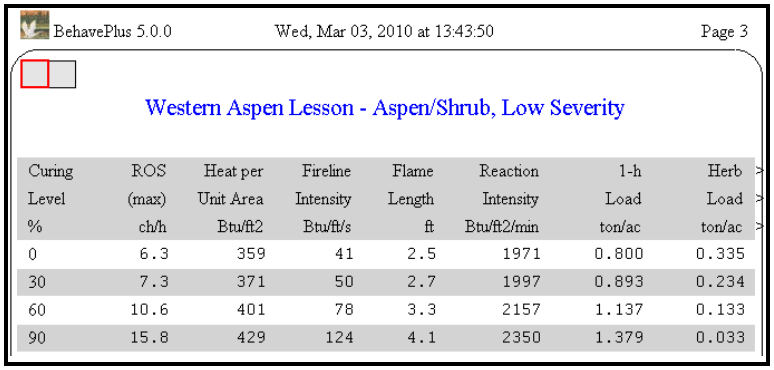
Aspen/shrub model, range of curing, low severity

- Click the **Calculate** button ( ).
- Choose to display both table results and graph results.



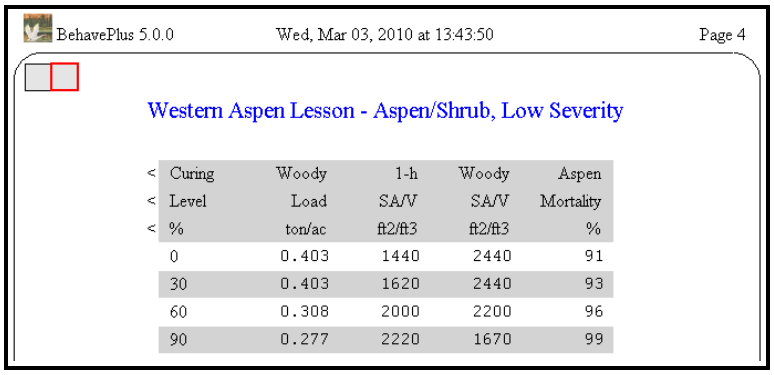
- Click **Ok**.

The outputs follow. There is one table, which comprises two pages (noted by the arrows on the right-hand side of the table and the red box in the upper left hand corner of the screen.



Curing Level %	ROS (max) ch/h	Heat per Unit Area Btu/ft2	Fireline Intensity Btu/ft/s	Flame Length ft	Reaction Intensity Btu/ft2/min	1-h Load ton/ac	Herb Load ton/ac
0	6.3	359	41	2.5	1971	0.800	0.335
30	7.3	371	50	2.7	1997	0.893	0.234
60	10.6	401	78	3.3	2157	1.137	0.133
90	15.8	429	124	4.1	2350	1.379	0.033

Note each of the fire behavior outputs shown above increases with increased curing level.



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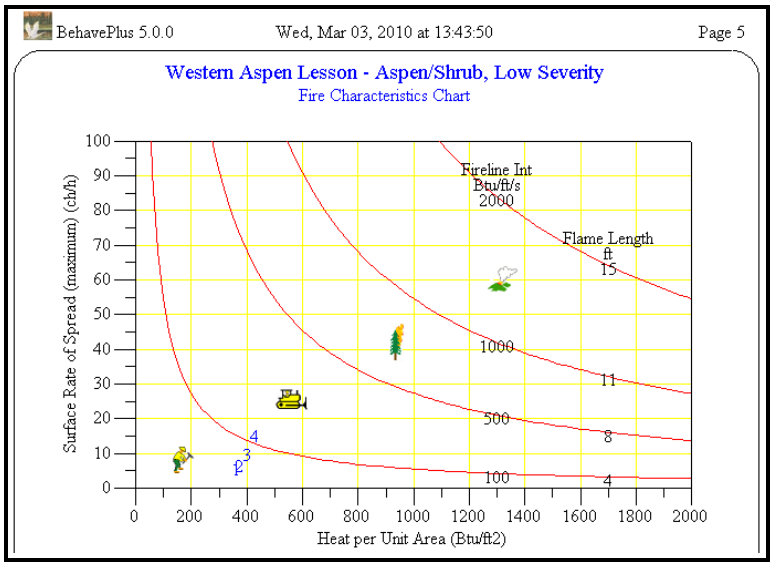
Western Aspen Lesson - Aspen/Shrub, Low Severity

< Curing Level %	Woody Load ton/ac	1-h SA/V ft2/ft3	Woody SA/V ft2/ft3	Aspen Mortality %
0	0.403	1440	2440	91
30	0.403	1620	2440	93
60	0.308	2000	2200	96
90	0.277	2220	1670	99

The aspen outputs follow the pattern described previously in the lesson. As Aspen Curing Level increases, 1-h Fuel Load and 1-h SA/V increase while Herbaceous Load, Woody Load and Woody SA/V decrease.

Our aspen stand is toast even though the fire behavior outputs seem moderate! See the Fire Characteristics Chart below. In the exercises you will explore parameters for successful burning without such high mortality.



Look at the rest of the graphical output from BehavePlus from your runs. Are the results the same as in the tables?

Summary

The special case fuel model for western aspen was developed following the work of Brown and Simmerman (1986) and Brown and DeByle (1987). The model uses some familiar variables such as fuel moisture, Midflame Wind Speed and Slope Steepness. However, additional variables for choosing one of five Aspen Fuel Models, and Aspen Curing Level are added to make this model's inputs different from those of standard or custom models.

The aspen model uses a unique method of fuel load transfer tied to the level of curing rather than the live fuel moisture content or direct input methods used for other standard and custom fuel models in BehavePlus.

In addition, inputs for D.B.H. and Aspen Fire Severity (along with calculated Flame Length) allow prediction of aspen mortality using a model unique to aspen rather than the MORTALITY module used for other fuel models in BehavePlus. Output variables specific to the aspen model include 1-h, Herbaceous and Woody Fuel Loads as well as 1-h and Woody SA/V.

References

Brown, James K.; Simmerman, Dennis G. Appraising fuels and flammability in western aspen: a prescribed fire guide. 1986. General Technical Report INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.48 p.

Brown, J. K.; DeByle, N. 1987. Fire damage, mortality, and suckering in aspen. Canadian Journal of Forest Research. 17: 1100-1109.

Scott, J. H. and R. E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. General Technical Report RMRS-GTR-153.Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Exercises

The following exercises will explore aspen outputs using each of the five fuel models. The exercises will also explore parameters necessary to limit (or enhance) aspen mortality. Prescriptions may range from maintaining aspen cover to removing an aspen overstory to enhance suckering. According to Brown and Simmerman (1986) fires having Flame Lengths greater than 1.7 to 2.1 feet will kill aspen trees. But, Flame Lengths of 1 to 1.5 feet are needed to sustain fire spread. Finding the balance between conditions adequate to sustain burning and maintaining adequate control and reaching mortality objectives can be challenging in this fuel type. Some inputs will follow information given in Brown and Simmerman (1986).

1. In the lesson example, our fuel inputs lead to very high aspen mortality. Use the following inputs to explore the effect of aspen D.B.H on mortality.
   - Use the Aspen/shrub model.
   - Aspen Curing Level ranges from "0" to "90" by "30"% steps.
   - D.B.H. ranges from "10" to "40" by "10" inch increments.
   - Fuel moistures are "8" for 1-h, "10" for 10-h.
   - Typically, live fuel moisture would decrease with increased curing. To simplify the entry, use "150" for live herbaceous and "85" for live woody moisture.
   - Midflame Wind Speed is "5" mi/h.
   - Slope is "0%".
   - Aspen fire severity is "Low."

2. Explore mortality through the other aspen fuel models using the same inputs as in Exercise 1, changing only the Aspen Fuel Model so that all four remaining aspen models are examined.

3. The 10-inch D.B.H. aspen are vulnerable to high mortality as shown in our previous exercises. This exercise will explore the effect of wind on fire behavior outputs and aspen mortality in the five aspen fuel models. Curing level will represent late summer or early autumn conditions ("50%") and dead fuel moisture values will be set at fairly high representing conditions (1-h at "12%" and 10-h at "14%") after some rain or with shorter days and longer periods of increased relative humidity at night. Live herbaceous is "150%", live woody at "75%." Midflame Wind Speed will range from "0" through "20" at "5" mi/h increments. There is no ("0%") slope. Aspen Fire Severity is "Low."

4. Just because I am curious (aren't you?), explore the outputs given a Moderate^{+} fire using the aspen fuel model with the flashiest and most benign fire behavior outputs. All other inputs remain the same as for Exercise 3. What fire behavior outputs are and are not affected by the change in fire severity?